Chapter 2 – Conceptual Models

INTRODUCTION

A conceptual model is a visual or narrative summary (or both) that describes the important components of an ecosystem and the interactions among those components (NPS 2003). Although they are simplifications of complex systems (Starfield 1997), models help synthesize current scientific understanding so that scientists can make defensible decisions on what to monitor with a better understanding of how indicators are linked to the broader ecosystem (DeAngelis et al. 2003, Maddox et al. 1999).

Weaknesses of past monitoring programs often stem from a lack of underlying heuristic models upon which the monitoring questions, sampling designs, analyses and interpretations were predicated (Niemi and McDonald 2004, Noon 2003, Noon et al. 1999). Well-designed conceptual models help formalize current understanding of system processes and dynamics, identify linkages of processes across disciplinary boundaries, identify the bounds and scope of the system of interest, and contribute to communication among all stakeholders. This chapter summarizes the process we used to develop and incorporate conceptual models in the selection and interpretation of Vital Signs for the GLKN parks.

Ecosystems and Authorship

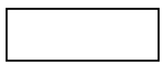
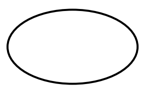
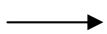
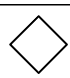
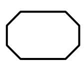
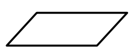
We selected six broad conceptual models: geological processes, inland lakes, Great Lakes, large rivers, northern forests, and wetlands. Network staff enlisted scientists with knowledge of these ecosystems or processes and a familiarity with the Network parks to write the conceptual models (Table 2.1).

Table 2.1. Great Lakes Inventory and Monitoring Network conceptual model authors and affiliations.

Model	Author(s)
Geological Processes	Walter Loope, USGS Great Lakes Biological Station
Inland Lakes	Paul Sager, UW-Green Bay
Great Lakes	Glenn Guntenspergen, USGS Patuxent Wildlife Research Center
Large Rivers	Ken Lubinski, USGS Upper Midwest Environmental Sciences Center
Northern Forests	Jerry Belant, NPS Pictured Rocks National Lakeshore Phyllis Adams, NPS Midwest Regional Office
Wetlands	Joan Elias, NPS Great Lakes Inventory and Monitoring Network Darin Carlisle, USGS Water Resources Division

The GLKN selected a stressor-based modeling approach to indicate links among important **stressors** and affected attributes. Model authors were asked to produce a narrative report with box-and-arrow schematics to represent key ecosystem components and linkages (Table 2.2). The combined strengths of the narrative and box-and-arrow diagrams convey important information and provide clear links to management issues.

Table 2.2 Components of the "Box-and-Arrow" conceptual models used by the Great Lakes Inventory and Monitoring Network to identify Vital Signs (adapted from NPS 2003).

Symbol	Model Component
	*Drivers* are major driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that influence natural systems across large areas.
	*Stressors* are physical, chemical, or biological perturbations to a system that are either foreign to that system or natural to the system but occurring at an excessive or deficient level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include air pollution, water pollution, water withdrawal, pesticide use, timber and game harvest, and land-use change. They act together with drivers on ecosystem attributes.
 or 	*Ecological effects* are the physical, chemical, biological, or functional responses of ecosystem attributes to drivers and stressors.
	*Attributes** are any living or nonliving environmental feature or process that can be measured or estimated to provide insights into the state of the ecosystem.
	*Measures* are the specific variables used to quantify the condition or state of an attribute or indicator. These are specified in definitive sampling protocols. For example, stream acidity may be the indicator; pH units are the measure.

* Vital Signs are a subset of attributes that are determined to be the best indicators of ecological condition, or respond to natural or anthropogenic stresses in a predictable or hypothesized manner, or have high value to the park or the public (e.g., endangered species, charismatic species, exotic species).

RESULTS OF MODELING

The six conceptual models are presented in their entirety in Gucciardo et al. (2004); a brief overview of each model is provided below along with its associated diagram. These conceptual models may need to be refined and expanded as the Network matures, collects monitoring data, and focuses on specific indicators. Nonetheless, the models in their current form provided a common understanding of the ecosystems and were used as a tool to help select the most critical Vital Signs for monitoring. The diagrams helped illustrate major causes of change (drivers and stressors) and how they are linked ecologically to potential measures.

Earth Processes (Figure 2.1)

General description

This model describes the geological and physical processes that formed and continue to modify the land in and around the Great Lakes Network parks. The entire upper Midwest was influenced by glaciers as recently as 10,000 years ago. The resulting landforms, soils and dynamic processes (e.g., erosion) in turn influence other terrestrial and aquatic systems.

Drivers and stressors

Climate is a major driver which causes natural fluctuations of Great Lakes water levels. This variability has driven quasi-periodic (approximately 150 years) lake level change over at least the past 5000 years (Thompson and Baedke 1997, Baedke and Thompson 2000). High lake levels have influenced coastal dune building and local hydrology (Anderton and Loope 1995, Loope and Arbogast 2000). Thus, the shores of several Network parks are naturally quite dynamic. Lake-level fluctuations drive changes in patch size, shape, and distribution of habitats required by several rare plant species. Along sandy portions of the Upper Great Lakes shorelines, propensity to change can differ greatly with position relative to streams of littoral sand drift and the texture of bluff substrate. The same lake level and storm surge behavior can result in bluff retreat, recession, or progradation depending on location (Chrzastowski and Thompson 1992).

All nine Network parks were covered by Wisconsinan glaciers, which left behind glacial drift (outwash, till, and lacustrine deposits) of various thicknesses. Upland landforms are subject to natural and anthropogenic erosion and sedimentation processes. Unconsolidated sandy deposits commonly occurring along lower landscape positions are regularly destabilized by natural fluctuations of the Great Lakes water levels (Bishop 1990, Colman et al. 1994, Anderton and Loope 1995, Arbogast and Loope 1999, Fisher and Whitman 1999).

Changes to natural features and processes often stem from construction of roads, trails, buildings, and other facilities. Alteration of natural processes most commonly results from placement of structures such as revetments, groins, and other shore armoring. Compaction of soils and hardening of the surface (i.e., pavement) along the shoreline of lakes and streams causes increased rates of water runoff and adds to sediment loads, pollution, and erosion. Visitor trampling can also compromise vegetation and promote erosion, though normally at a smaller scale. Human-caused changes in climate could result in altering water levels and changing the hydrological cycle.

Indicators

Some important indicators within the Earth Processes model include rates of soil transport, rates of bluff retreat, rates of beach recession/progradation, stream bank stability, stream sinuosity and erosion, dune building and stabilization, populations of rare shoreline plants, stream sediment load, longshore sediment transport, stream flow regime, and Great Lakes water levels.

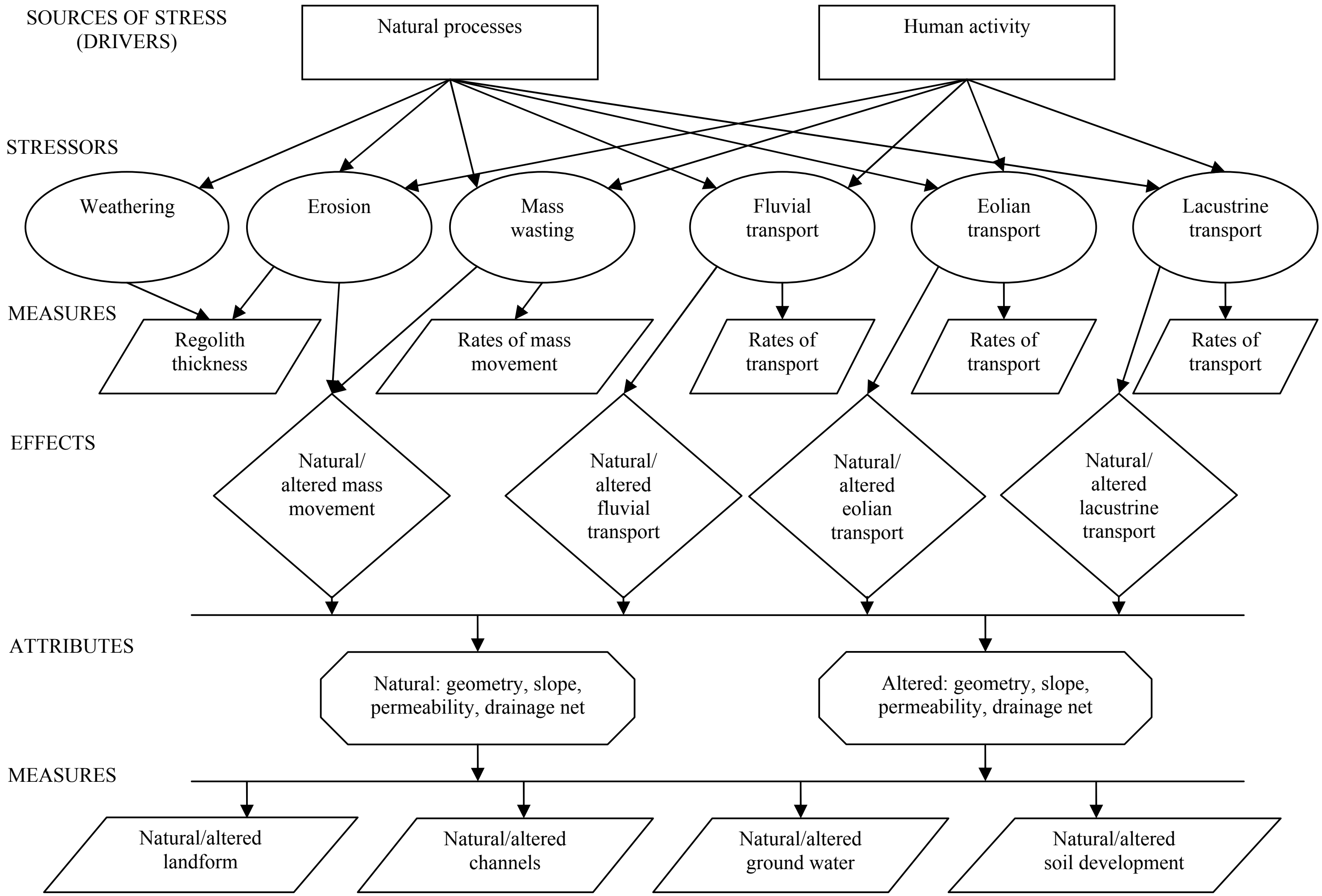


Figure 2.1. Conceptual physical model of the Upper Great Lakes. Model developed for the NPS Great Lakes Inventory and Monitoring Network of Parks to illustrate connections between selected attributes (Vital Signs) and system drivers.

Inland Lakes (Figure 2.2)

General description

Inland lakes are highly valued for the recreational opportunities and aesthetic experiences they provide. They have also attracted scientists for ecosystem studies because of their diversity, relative ease of isolating specific subunits, the ability to conduct ecosystem-level manipulations and to document changes in the global environment (Davis 1981). Because they are sensitive to inputs from the watershed and air sheds, lake ecosystems in most or all areas of the world have likely experienced at least some level of human-induced, ecological change.

To be useful, a conceptual model of a lake ecosystem must be general enough to address the diversity of lake types encountered at even a regional level. The diversity arises in the form of many features of lakes including:

- Trophic status (oligotrophic, eutrophic, dystrophic, etc.)
- Annual mixing pattern (dimictic, polymictic, meromictic)
- Morphometry (depth, volume/area, shoreline development, mean slope, etc.)
- Water Source (stream inlet, groundwater seepage, precipitation)

Responses of lake ecosystems to stressors may vary considerably in duration depending on the type of disturbance and the sub-system affected. Frost et al. (1988) emphasize the importance of recognizing the variations in scale in studying and understanding lake ecosystems. Hence, lakes may show responses on evolutionary time scales (e.g. predator-prey associations) (DeAngelis et al. 1985) to time scales of seconds (e.g. phosphorus cycling) (Norman and Sager 1978). On intermediate scales, exotic crayfish has been shown to alter the littoral community for several years (Lodge and Lorman 1987).

Drivers and stressors

Drivers can be both natural and anthropogenic. Major events such as extreme precipitation and runoff, fire, and erosion are natural drivers that foster increases in nutrient loading or hydrological washout, leading to changes in the lake of varying duration. Lakes are sensitive to events and processes external to their basins. Features of the lake itself, such as basin morphometry, water clarity, and food chain structure, interact with the external influences to modify how change affects the lake ecosystem.

Anthropogenic watershed disturbances such as agriculture, urban development, logging, and fire are major influences on lake ecosystems (Scrimgeour et al. 2001, Garrison and Wakeman 2000). Loss of protective vegetative cover on soil leads to increased loading of nutrients and sediments, which increases growth of phytoplankton and submersed aquatic vegetation.

Shoreline disturbances such as clearing emergent and submersed vegetation and removing woody debris can lead to loss of aquatic habitat, decreased amphibian populations (Woodford and Meyer 2003), reduction in fish growth rates (Schindler et al. 2000), and decreased water quality (Garrison and Wakeman 2000).

Atmospheric deposition of contaminants illustrates the broad extent to which lakes are affected by factors external to the basin. The watershed area for a given lake in most cases is small in comparison to the air shed. Mercury can enter lakes via atmospheric deposition and is a problem in water bodies throughout the Great Lakes region.

Deposition of oxides of sulfur and nitrogen from combustion of fossil fuels causes acidification of lakes. Atmospheric transport may be over great distances or from nearby sources. Acidification of lakes is significant for its broad ranging ecological effects as well as its influence on the methylization of mercury.

Recreation activities are increasingly regarded as a major influence on lake ecosystems. Considerable pressure from fishing and boating can lead to impacts on the age and size structure of fish populations and the food web (Reed-Andersen et al. 2000, Landres et al. 2001, Harig and Bain 1998). Introduction of invasive and exotic species can occur when boats carrying entangled biota are moved from lake to lake (Johnson 2001).

Climate change could become one of the most serious anthropogenic influences on lake ecosystems. An increasing number of scenarios and predictions suggest the effects of climate change on lakes include nearly all communities and processes via altered temperature regimes, hydrologic patterns, and interactions with numerous other stressors. However, Davis et al. (2000) suggest that inland lakes near the Great Lakes may experience less extreme changes because of the moderating effect on temperature of the large water bodies.

Stressors from the above drivers include nutrient and sediment loading, habitat loss, increased loading of toxics, acid deposition, introduction of exotic species, increased recreational pressure, and changes in temperature and precipitation.

Indicators

Indicators that could be monitored for inland lakes include phytoplankton and zooplankton communities, water clarity, littoral community (including submerged aquatic vegetation and periphyton), hyplolimnetic oxygen deficit, fish community, shoreline habitat, organism health, sediment/water quality, annual temperatures, and lake levels.

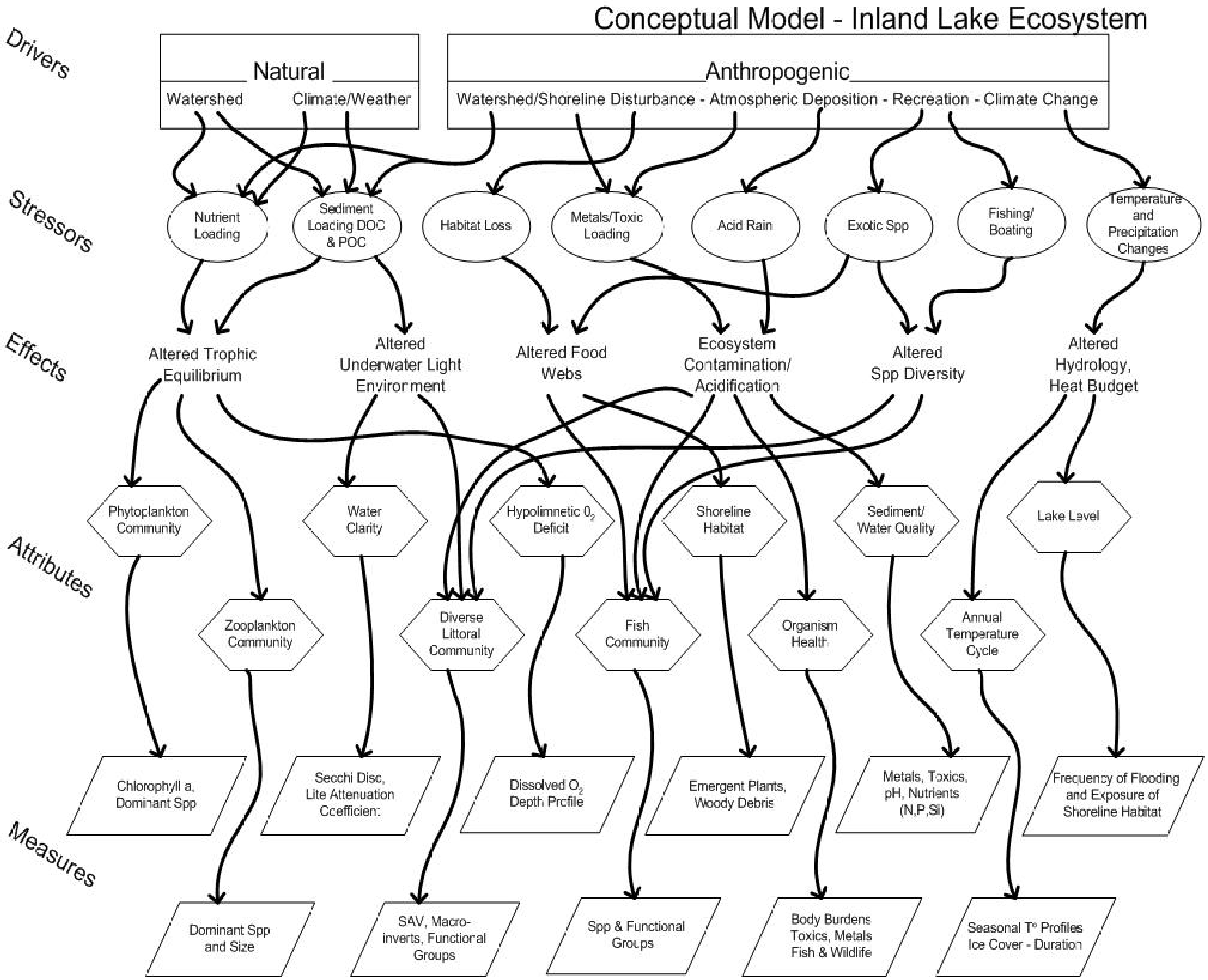


Figure 2.2. Inland lakes conceptual model for the Great Lakes Inventory and Monitoring Network.

Large Rivers (Figure 2.3)

General description

This conceptual model was developed primarily to cover the Mississippi River (MISS) and the St Croix, and Namekagon Rivers (SACN), but it may also be useful for large rivers at other Network parks. Throughout the world, large rivers and tributary networks have been important as highways for human travel and commerce. Hence, humans have built next to them and altered their physical templates and hydraulic dynamics (Welcomme 1985, Dynesius and Nilsson 1994, Galat and Frazier 1996).

Within a basin, as rivers increase in size in the downstream direction, predictable gradients occur in the forces that shape the stream, control the substrate, and provide organic material (Vannote et al. 1980). Large rivers tend to occur at lower elevations than smaller streams within the same basin. They also often have shallower elevation gradients than their tributaries and therefore trap more sediment and have longer water retention times. These conditions, with the exception of local areas where the channel is constricted, generally result in lower water velocities and substrates dominated by finer particles. Under natural conditions, the discharge of a river increases with distance downstream. The predictability of the flow regime of a large river is typically greater than the predictability of its smaller, flashier tributaries (Johnson et al. 1995).

Under natural conditions, the primary sources of energy in a large river, detritus, fine particulate organic material, and attached bacteria, are usually allochthanous, that is, carried downstream by tributaries. The River Continuum Concept (Vannote et al. 1980) holds that local photosynthesis in large rivers is limited by turbid water. However, the presence of dams, floodplains with large backwaters, or large amounts of woody debris in a given large river reach can reset energy processes to conditions more like those that occur in moderate size streams (Ward and Stanford 1983, Junk et al. 1989, Thorp and DeLong 1994, Bayley 1995). Under these conditions, there are increases in in-stream (autochthanous) invertebrate production and energy production through photosynthesis.

In large rivers with substantial floodplains, annual flood pulses have been identified as perhaps the most important hydrologic feature that governs year-to-year changes in ecosystem productivity and possibly diversity (Junk et al. 1989, Ward 1989).

Large rivers frequently exhibit distinctive reach or microhabitat characteristics that are attractive to individual or groups of species (Stalnaker et al. 1989, Montgomery and Buffington 1998). Reaches are frequently distinguished by different vegetation patterns, community types, and habitat assemblages (Lubinski 1993). Microhabitat attractions are often observed during specific life history stages, seasons, or discharge ranges. An especially important characteristic of large rivers is that conditions in their microhabitats change widely with river discharge (Reash 1999). Population changes in response to year-to-year variations in discharge are considered to be an important contributor to riverine biodiversity (Knutson and Klass 1997, Galat et al. 1998).

The flora and fauna of large rivers are adapted to and controlled in large part by the conditions discussed above. It is also important to keep in mind however, that large-scale distribution patterns of many species, terrestrial and aquatic, in the Midwest still reflect zoo-geographic patterns established by glacial land forming processes that occurred thousands of years ago.

Large rivers, within the context of either their tributary networks or even broader spatial scales, function as landscape corridors (Lubinski and Theiling 1999). In this role, they provide ecological services such as removing wastes, and transporting nutrients, sediments and water itself, to systems downstream. The landscape corridor function of large rivers is of special value to migratory birds and fishes. This function may even extend beyond a river's basin, as in the case of the Mississippi and St Croix Rivers, which provide migration corridors between continents for many waterfowl and neo-tropical bird species (Knutson and Klass 1997).

Drivers and stressors

The ecological condition of a large river depends on drivers and stressors that exist at multiple spatial scales (Frissell et al. 1986, Lubinski 1993, Naiman 1998). Drivers that operate at larger spatial scales tend to exert control over longer temporal scales and cycles (Poff and Ward 1990, Naiman 1998). Drivers identified in the Large Rivers model include underlying geology; land cover and use; climate; anthropogenic use of the river, such as for barge traffic, recreation, dredging and filling, creation or removal of barriers, and resource extraction; and point and non-point source pollution.

Indicators

The selection of attributes for monitoring large rivers was based on Karr's (1991) view of primary stream ecosystem elements. The final number of attributes was narrowed to the following four, that could function in an operational monitoring program and would meet the NPS emphasis on trend detection: 1) native species, as measured by composition, abundance, and distribution; 2) water quality, including measures of physical and chemical variables; 3) physiography of the floodplain and channel, as measured by habitat diversity, connectivity, and fluvial dynamics; and 4) flow regime, including discharge, velocity, and water level elevation.

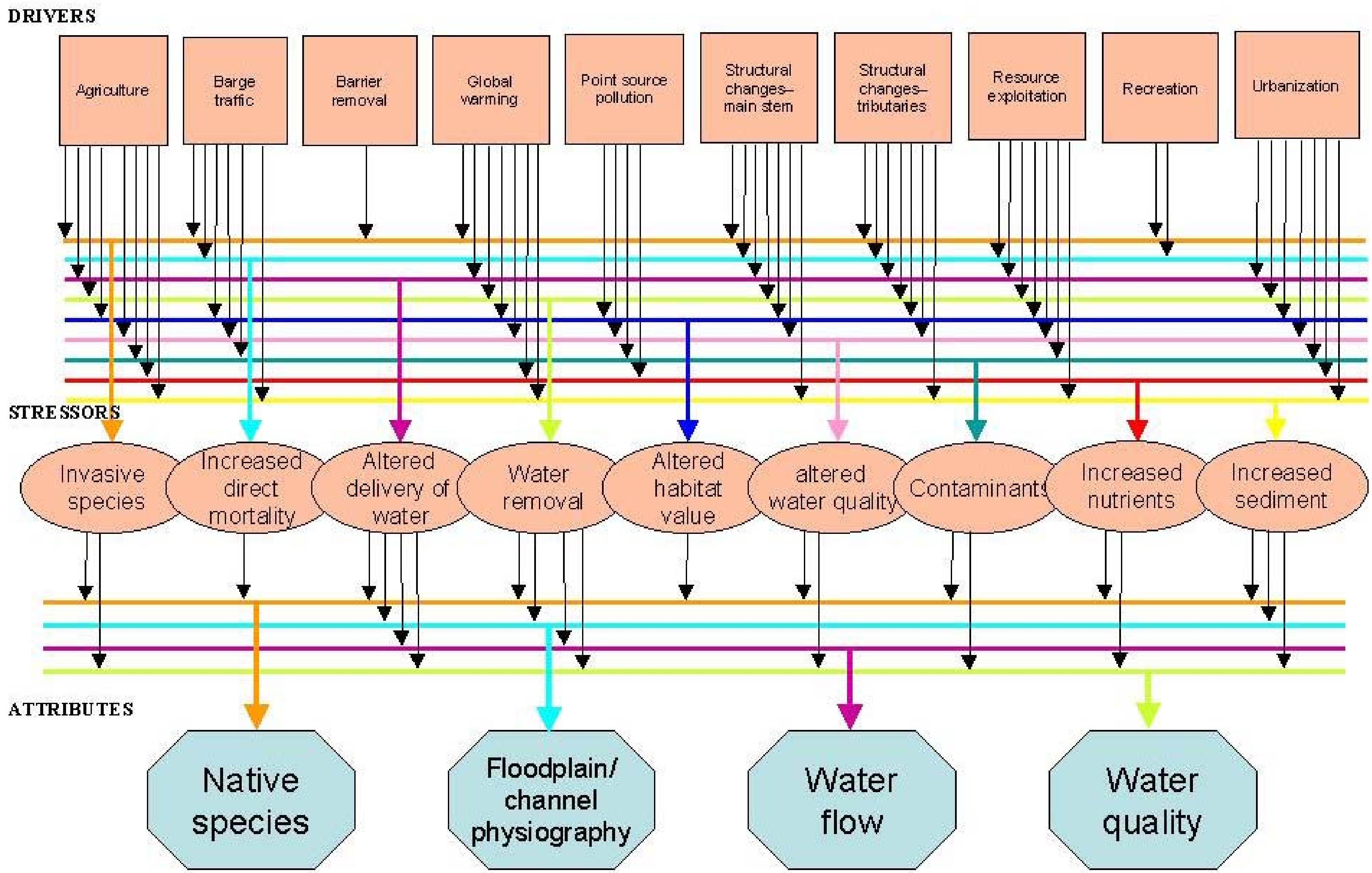


Figure 2.3a. Relationships between anthropogenic drivers, stressors and coarse-level attributes in a large river model. Each stressor (ovals) and attribute (octagons) are represented by thick, colored lines. Connections (probable causal linkages) between drivers (rectangles) and stressors, and between stressors and attributes, are drawn with thin vertical arrows.

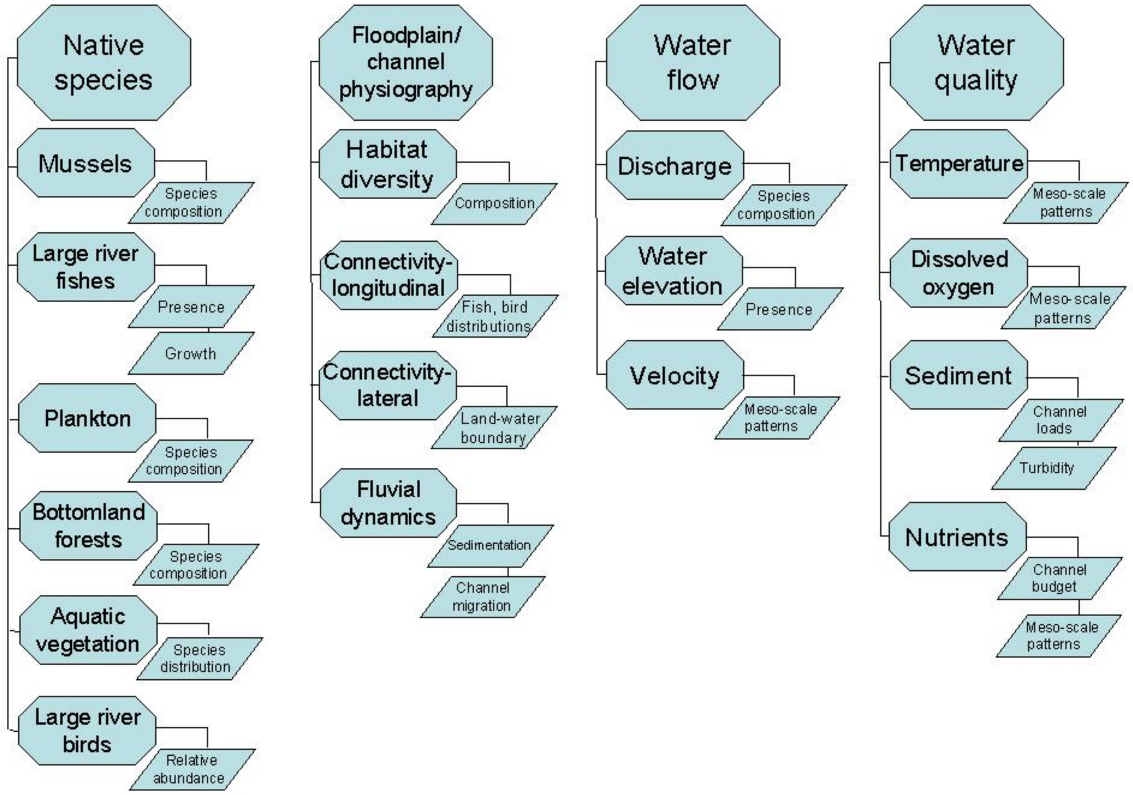


Figure 2.3b. Large river conceptual model relationships between attributes and measures. General attribute categories (larger octagons) are divided into fine-level classes for which specific measures are suggested (parallelograms).

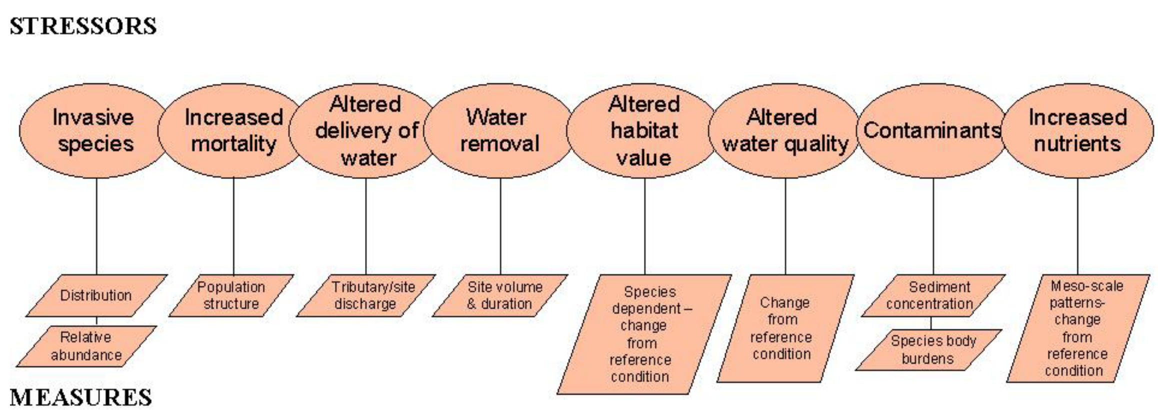


Figure 2.3c. Large river conceptual model relationships between stressors and measures. Direct effects from various stressors (ovals) can be monitored with appropriate measures (parallelograms).

Northern Forests (Figure 2.4)

General description

Forests overall comprise the largest single broad vegetation classification type in the Great Lakes region. In general, forests contain greater biological diversity than any other terrestrial vegetation type (Ricklefs 2001). At the time of European settlement, forests covered about half of the conterminous United States (Spies and Turner 1999). Worldwide, they are important for maintenance of biotic diversity, nutrient cycling, and consumptive and nonconsumptive human activities. Hunter (1999) describes forests and their associated diversity as having ecological, economic, educational, scientific, and spiritual values. Within the Great Lakes Network there are two conifer- and five deciduous-dominated forest types (Barbour et al. 1999). The conifer forests of the Network are the boreal forest and Great Lakes pine forests; the deciduous forest types are the northern hardwoods ecotone, maple-basswood forest, beech- maple forest, oak savanna ecotone, and oak-hickory forest.

Drivers and stressors

In this forest model, the three principle drivers are human development, resource extraction, and natural processes. They exert effects through eight principal stressors as described below:

Fire, insects and disease, herbivory, and climate/weather are important natural stressors. Fire has a profound effect on all terrestrial ecosystems, affecting soils, hydrology, biotic communities, and nutrient availability (DeBano et al. 1998). Maintenance of several forest types requires periodic fire. Insects such as spruce budworm have had widespread effects on forest landscape patterns, community structure, and succession. Climate has a strong influence on ecosystems and is considered the major force defining boundaries of terrestrial biomes (Barbour et al. 1999). Weather can also have profound effects on forests including windthrow and precipitation patterns and events (e.g., ice damage). Larger scale weather events such as El Nino, which is associated with periodic changes in air pressure patterns over portions of the Pacific Ocean, strongly affect all terrestrial ecosystems, including forests. Insects and disease can have major effects on forest composition and structure through defoliation or direct mortality to plants. In boreal systems insects can affect areas equal to or greater than fire (Hall and Moody 1994). Gypsy moths (*Lymantria dispar*) have defoliated large tracts of forest in eastern North America and are moving in to the western Great Lakes region. Although herbivores rarely consume >10 percent of forest vegetation (Ricklefs 2001), herbivore population irruptions have had substantial effects on forest communities. For example, insect outbreaks have defoliated large forested areas and unnaturally high white-tailed deer populations have altered diversity and composition of forest plant communities throughout eastern North America, including the Great Lakes region (Stromayer and Warren 1997, Waller and Alverson 1997).

Important anthropogenic stressors identified for the forest model include pollutant/chemical loading, invasive exotics, habitat loss/fragmentation, harvest, and fire or fire suppression. Pollution, particularly atmospheric pollution, threatens the environment on a global scale (Barbour et al. 1999). Invasive species have altered virtually every ecosystem on earth. It has been estimated that >50,000 exotic species have been introduced to the United States alone (Ricklefs 2001). Human settlement patterns have resulted in loss and fragmentation of forests for thousands of years, leading to pronounced changes in abundance and distribution of forest communities. In northern Wisconsin, timber harvest has resulted in predominantly second growth forests in what was formerly old-growth eastern hemlock and mature northern hardwoods (White and Mladenoff 1994, Spies and Turner 1999). Human-altered landscapes have provided highly desirable habitat for white-tailed deer (e.g. conversion of conifer forest to aspen forest and agricultural fields). This has caused high numbers of deer in many areas of the Great Lakes region and deer have greatly altered forest communities. Human-initiated fires change surface organic materials and nutrient storage (DeBano et al. 1998). Both fire and fire suppression alter forest succession and associated community structure.

Indicators

The stressors and the effects on forested ecosystems described above are best represented by the following 11 indicators (and associated measures):

- Physiology/organism health (histology, reproduction, bioaccumulation, growth rate)
- Abiotic transport and storage (air deposition, contaminant concentration in soils)
- Soil characteristics (erosion, temperature, water storage, structure)
- Habitat mosaic (patch characteristics, connectivity, edge)
- Hydrology (evaporation, transpiration, runoff, infiltration)
- Population demographics (recruitment, survival, dispersal, density)
- Biotic diversity (species composition, relative abundance)
- Succession (regeneration, structure, replacement rate)
- Trophic relations (competition, herbivory, predation)
- Primary production/decomposition (process rates, biomass)
- Soil quality and chemistry (N/P pools, temperature, organic layer)

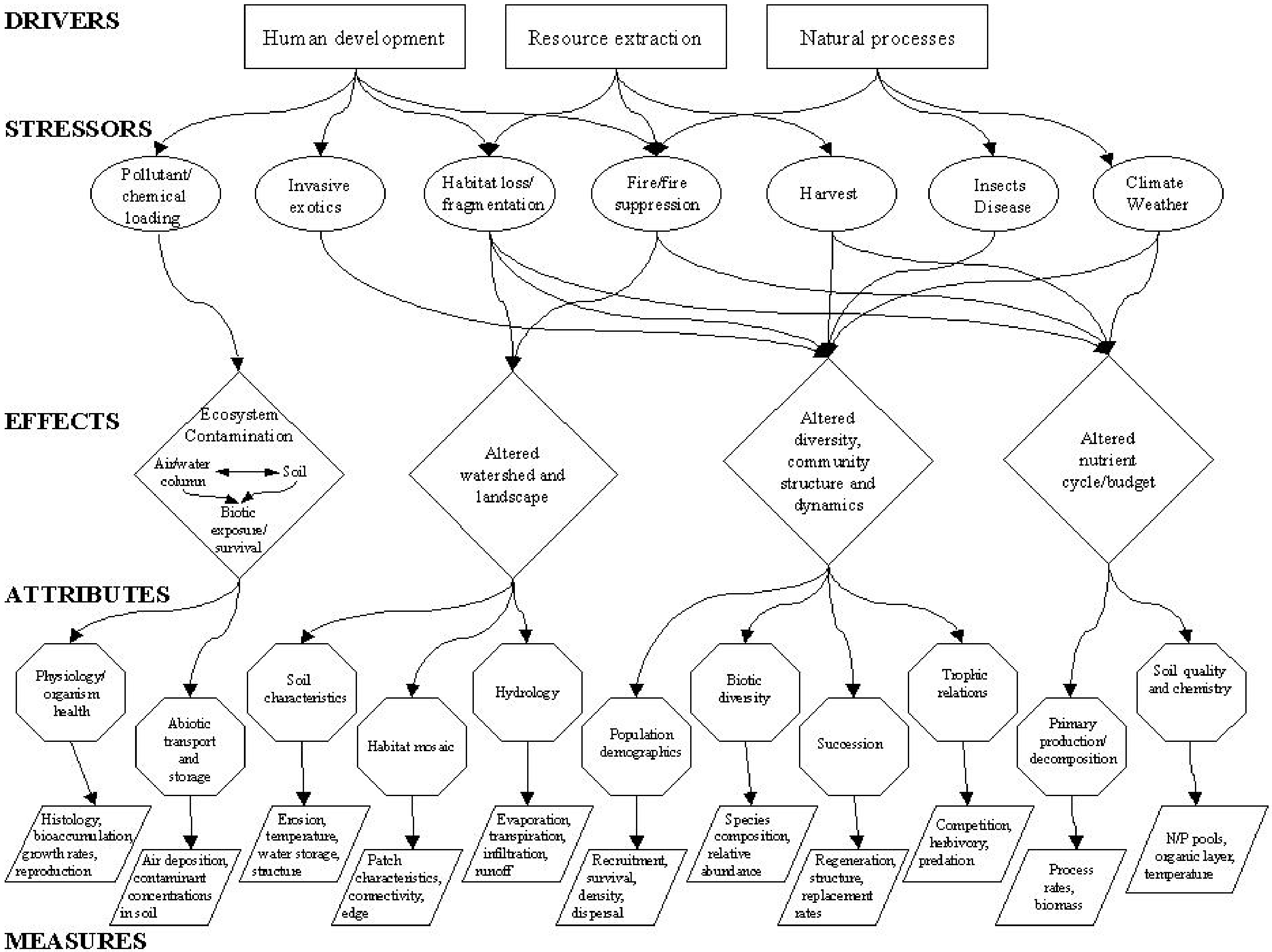


Figure 2.4. Great Lakes forest conceptual model. Model developed for the NPS Great Lakes Inventory and Monitoring Network to illustrate connections between selected attributes (Vital Signs) and system drivers.

Wetlands (Figure 2.5)

General description

The term wetland is a generic descriptor of a wide variety of places, including marsh, wet meadow, swamp, bog, fen, and muskeg. The commonality is the presence of standing water or saturated soils during at least a portion of the growing season. Wetlands exist in places where surface water periodically collects, including depressions surrounded by upland, with or without a drainage system; relatively flat, low-lying areas along major water bodies; shallow portions of large water bodies; and sloped areas below sites of groundwater discharge.

Although wetlands cover a relatively small portion of the world's land surface (approximately 4-6 percent, Mitsch and Gosselink 2000), their ecological and societal values are disproportionately great. Some of these values are flood storage; sediment retention; improvement of water quality; shoreline stabilization; erosion control; habitat for plants, fish, and wildlife; biodiversity reservoir; groundwater recharge; and food web production and export (Maynard and Wilcox 1997, Tiner 1999).

Despite the obvious benefits of wetland environments, they have been extensively modified or destroyed by human activities. In the contiguous United States, approximately 53 percent of all wetlands have been lost in the last two centuries (Mitsch and Gosselink 2000). This widespread destruction of wetlands was accomplished through a variety of activities that altered the hydrology or contaminated the water. Currently, wetlands are the only ecosystem type that is comprehensively regulated across all public and private lands within the United States (National Research Council 1995). The federal Clean Water Act, Section 404, provides protection of wetlands across the nation, but each state has jurisdictional authority to add further requirements.

Drivers and stressors

For the purposes of this model, 'Ecosystem Drivers' refers to the major natural and anthropogenic forces that influence wetland ecosystems. Anthropogenic drivers may disrupt natural processes (e.g., the presence of a harbor or breakwater interrupting the transport of sediments along the shoreline) or occur within the context of natural processes (e.g., the introduction of exotic species during periods of naturally low water levels).

Each ecosystem driver exerts stressors on the ecosystem. Natural stressors to wetland ecosystems include changes in water levels, changes in sediment supply and transport, climate, weather, succession, and biological disturbances. Hydrology is the most important factor in wetland ecosystem maintenance and processes, affecting biogeochemical processes, nutrient cycling and availability, and biological communities (Environment Canada 2002). Addition of sediments to wetlands affects vegetation, water quality, and faunal communities. Transport of sediment along Great Lakes shorelines affects the connectivity of coastal wetlands to direct lake influences. Climate (which is also influenced by anthropogenic activities) affects the floral and faunal communities present in wetlands, as well as water levels. Weather introduces a number of possible disturbance events, such as ice scouring, wave action, and extreme storm events. Succession occurs in wetlands through the accumulation of organic matter, such as peat, and through directional changes in water levels. Several biological stressors may affect wetlands, such as the spread of invasive native plant species (e.g., reed canary grass (*Phalaris arundinacea*)), activities of beaver (*Castor canadensis)*, herbivory (e.g., insects, muskrat (*Ondatra zibethica*), moose (*Alces alces*), waterfowl), and disease.

Anthropogenic stressors to wetland ecosystems include draining, filling, dredging, change in sedimentation, road crossings, shoreline modification, nutrient enrichment, toxic chemicals, water level stabilization, fire suppression, introduction of non-native species, and modification of climate. Many of these stressors are inter-related (e.g., a road crossing may restrict water flow from one part of a wetland to another, hence stabilizing water levels; road crossings increase the chance of introducing exotic plant species) and are due to agriculture and development or urbanization.

Indicators

Physical and chemical indicators include: hydrologic regime, and specifically, water level fluctuation; water chemistry; nutrient balance in water and sediments; primary productivity; decomposition; sediment supply, chemistry, and characteristics; turbidity; and the presence and concentration of toxins.

Indicators at the individual, population and community levels include: organism physiology and health, the concentration of toxins in tissues, population dynamics of wetland-dependent animals, presence and abundance of species especially sensitive to contamination, presence and abundance of exotic species, area covered by different vegetation types (e.g., submergent, emergent), plant and animal community composition, native and total biodiversity, and biotic community indices.

Landscape level indicators include the size, position, and number of wetlands, as well as land use and land characteristics in the vicinity of wetlands.

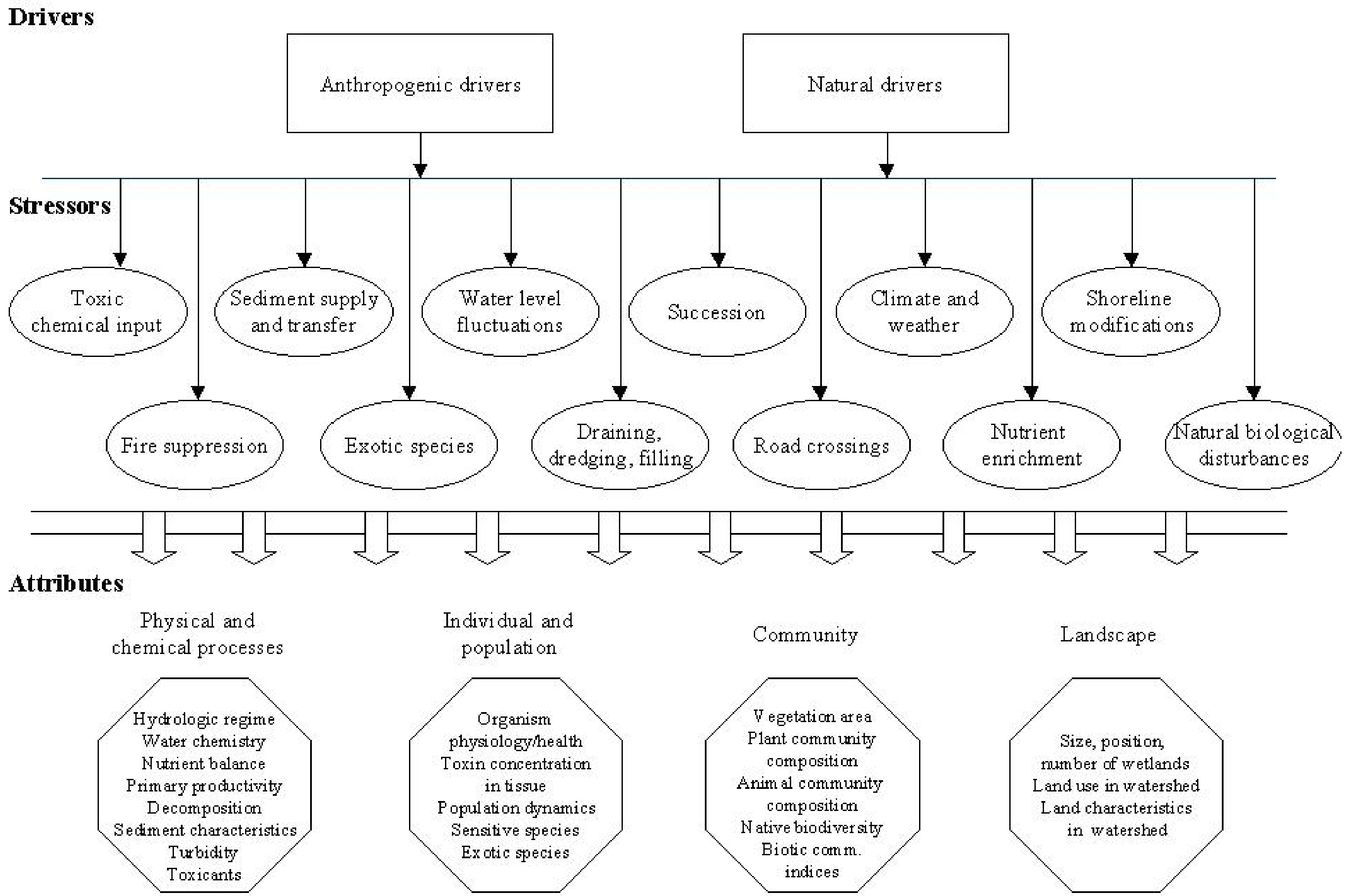


Figure 2.5a. Great Lakes wetland conceptual model. Model developed for the NPS Great Lakes Inventory and Monitoring Network to illustrate connections between system drivers (rectangles) and attributes (octagons).

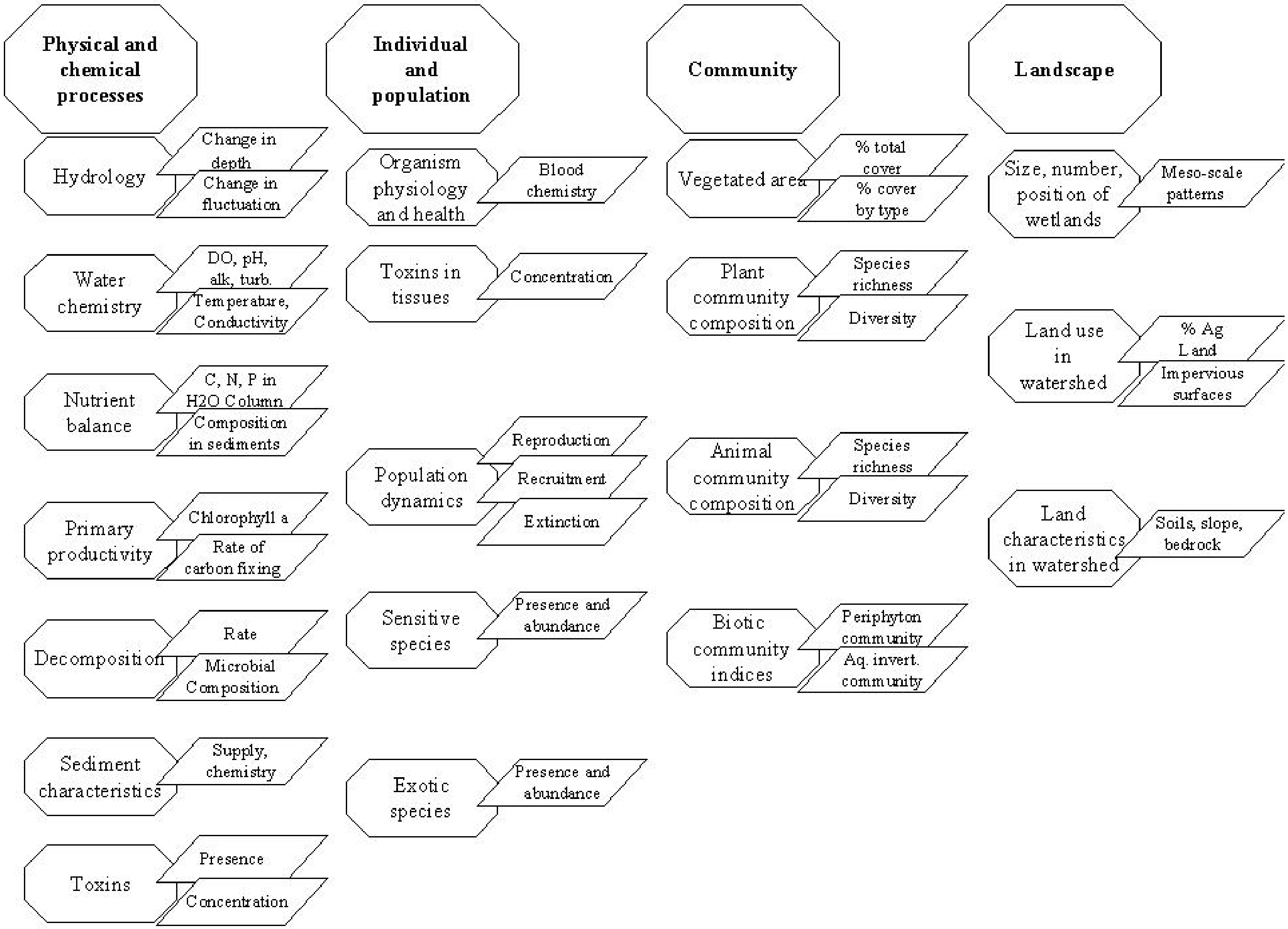


Figure 2.5b. Great Lakes wetland conceptual model attributes and measures. Model developed for the NPS Great Lakes Inventory and Monitoring Network to illustrate subgroups within major attribute categories (octagons) and representative measures of attributes (parallelograms).

USE OF CONCEPTUAL MODELS IN THE GREAT LAKES NETWORK

Conceptual models of the major Great Lakes Network ecosystems served two functions during the development of the program. First, they provided ecological context by summarizing the most important components and processes, putting these components and processes to scale spatially and temporally with illustrations of linkages between components, and by identifying the current and potential threats. Secondly, and as a result of the synthetic process of building the models, they helped us identify, prioritize, and select an initial set of Vital Signs for implementation. In chapter 3 we lay out the process we used for selecting and prioritizing Vital Signs, which included using the models. Refer Table 3.2 for a crosswalk between the selected Vital Signs and the models.

In addition to their value in summarizing information and helping select our Vital Signs, the models will continue to be useful during implementation. The ultimate goal of monitoring is to provide park managers with information to make science-based management decisions and to evaluate the effectiveness of various actions. The models provide a mechanism of communicating the results of monitoring by showing linkages among Vital Signs and the complex interactions of natural and anthropogenic processes. We expect the models will be an invaluable tool to help interpret monitoring results and explore alternative courses of action.

We expect to use the information provided in the conceptual models to develop more refined models or illustrations for specific issues. For example, we have adopted many of the indicators illustrated in Figure 2.6, including Land Cover/ Land Use, Terrestrial Vegetation, Air Quality, Water Quality, Fish Communities, and Trophic Bioaccumulation. Several of these have formed the initial set of Vital Signs being monitored by the Network (see Chapters 4 and 5). Illustrations such as this will be used to present results to other scientists, park managers, and the public in a straightforward and easily understood manor. It serves to make the information more relevant by illustrating how the data are linked to resources. The peer-reviewed conceptual models summarized here, and detailed in Gucciardo et al. (2004), will be the scientific basis for such illustrations.

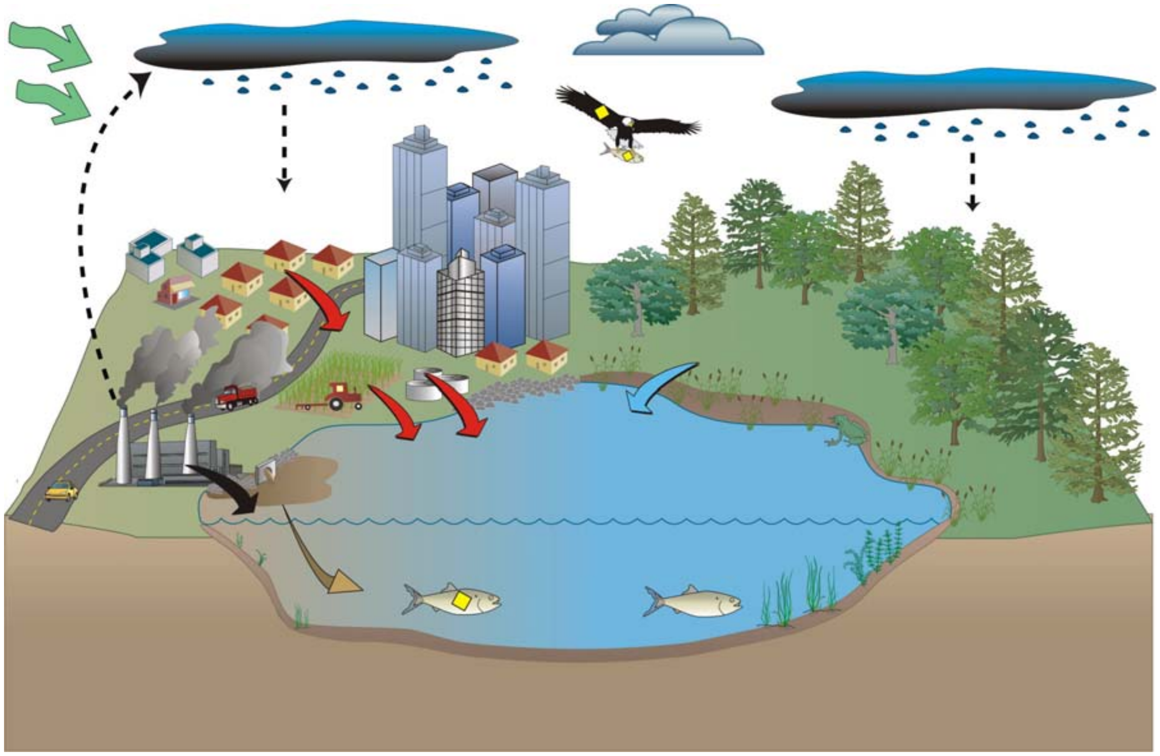


Figure 2.6. Illustration of how weather and land use influence water quality and cause contamination in fish and wildlife. Prevailing weather (green arrows) can drive polluted air over the landscape and deposit contaminants (black dashed arrows) onto water and land. Rainwater runoff across urban, industrial, and agricultural land (red arrows), combined with point-source pollution (black arrow) and sedimentation (brown arrow), will alter water quality. Some contaminants will bioaccumulate in higher trophic levels (yellow diamond in fish and bald eagle). Healthy ground cover in the form of terrestrial and aquatic vegetation can provide a buffer to reduce water pollution (blue arrow).